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Leveraging Sentinel Imagery to Model Aboveground Biomass and Estimate Carbon in Tajikistan's Pamir Mountains

Introduction

The Pamir Mountains in Tajikistan, shown in Figure 1, have undergone extreme landscape degradation in the past 50 years (Kasymov et al., 2022, p. 2). The Pamirs, with high elevation and arid climate, are at risk of natural disasters such as landslides, mudflows, and drought (Gavaldão et al., 2022). When the Soviet Union collapsed and the Tajik Civil War began, fuel subsidies ended, forcing people to harvest wood for heating and cooking and leading to extensive forest loss (Hoeck et al., 2007, p. 48). In 2018, Tajikistan's government made a Bonn Challenge pledge to restore 66,000 hectares of degraded landscape by 2030, and in February 2022, the World Bank approved a $45 million grant towards this goal (Dade, 2022).

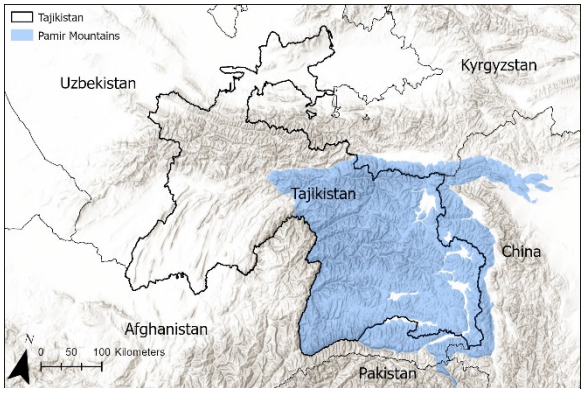

Figure 1: Area of Interest. This study will examine the area of the Pamirs that are in Tajikistan.

This project aims to quantify and map reforestation projects to understand where Tajikistan stands on its Bonn Challenge pledge. I will then do two aboveground biomass (AGB) models: 1) to estimate the ABG of the forest in 2017 (pre-pledge), and 2) to predict how 66,000 additional hectares of forest would affect ABG accumulation in the next 50 years. The purpose of studying biomass in this area is to better understand the region's capacity for carbon sequestration and how reforestation would increase that capacity.

Methods

This study will be divided into two sections, as outlined in Figure 2; the first determines changes in forest cover from 2017 (pre-pledge) to the present day to validate and quantify land restoration efforts, and the second uses this data to predict biomass with and without additional reforestation. The data required is publicly and freely available. The requirements are as follows:

- Sentinel 1: Synthetic Aperture Radar (SAR)
- Sentinel 2: blue – SWIR bands
- SRTM: Digital Elevation Model
- Precipitation: Climate Hazards Group InfraRed Precipitation with Station Data
- Soil: FAO's Digital Soil Map of the World
- Climate: World Bank Climate Change Portal
- Species information: *Betula pamirica, Salix* species, *Juniperus* species, *Populus pamirica* (Breckle & Wucherer, 2006)

Part 1: Forest Cover Change Detection: Using Sentinel-2 imagery, I will classify land cover into five classes (forest, water, barren, agriculture, and developed) for 2017 and the present. This process entails selecting training data, applying classification algorithms, and results validation. This process will also be enhanced by calculating Normalized Difference Vegetation Index (NDVI) and delineating forest cover based on NDVI values. By comparing the extent classified as forest in 2017 and the present, changes in forest cover over time will be quantified by reporting the number of hectares of increase, decrease, and no change in forest cover. This step, shown in Figure 2-Part 1, achieves the project goal of validating regional reforestation.

Part 2: Biomass Estimation: The forest cover estimated above will be combined with Synthetic Aperture Radar (SAR) data will be combined with environmental variables, including climate, soil, and precipitation data, as shown in Figure 2-Part 2. I will first use allometric equations and/or machine learning algorithms to estimate current biomass (Li et al., 2020). To predict future biomass, I will use the Physiological Processes Predicting Growth (3PG) model to estimate biomass accumulation, factoring in changing climate conditions (Gupta & Sharma, 2019). While 3PG is a simplification of the dynamics of forests, it is still a useful tool to make broad predictions. The biomass prediction process will be run on both the current forest extent and with an additional 66,000 hectares. If reforestation has already occurred, these areas will be identified spatially in Part 1. Otherwise, they will be assumed to be in floodplains(Breckle & Wucherer, 2006, p. 229). This approach allows for a comparative analysis of biomass with and without further reforestation.

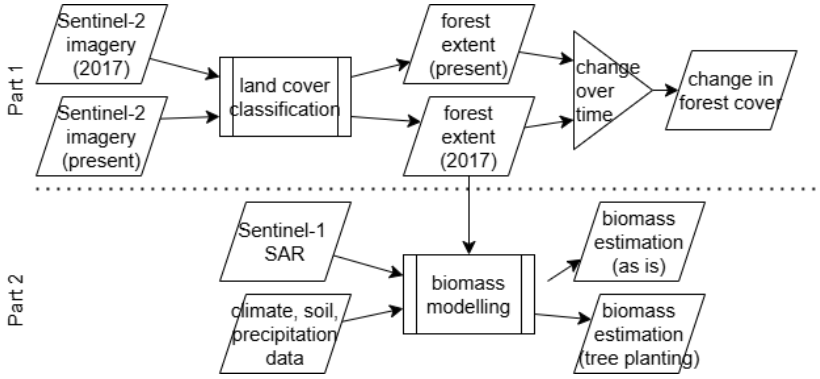

Figure 2: Proposed workflow. The study is in two parts, with the second dependent on the classification results from the first.

Expected Results and Significance

I expect this study to show that an expansion in forest extent since 2018. The unmet Bonn Challenge goals likely reflect a lack of reporting, not of restoration, as NGOs have independently reported their efforts (KfW, 2019; *Tajikistan Trees*, n.d.). I also expect to show that accumulation of biomass, and carbon sequestration, will be significantly higher if the 66,000 hectares are achieved, as illustrated in Figure 3. Predicting the amount of biomass is difficult as the amount of forest cover in the Pamirs, in both 2018 and present, is unknown (thus the need for Part 1), though I expect it to be millions of tonnes.[1]

These results' significance is in demonstrating that the country is on track with its restoration commitments and should receive further funding. Ongoing land degradation is not only an environmental concern but also has economic costs, so improving landscape resilience will have impacts on livelihoods and the government's capacity to fund other development initiatives. This data provides insight into similar high-elevation ecosystems and demonstrates restoration verification through remote sensing.

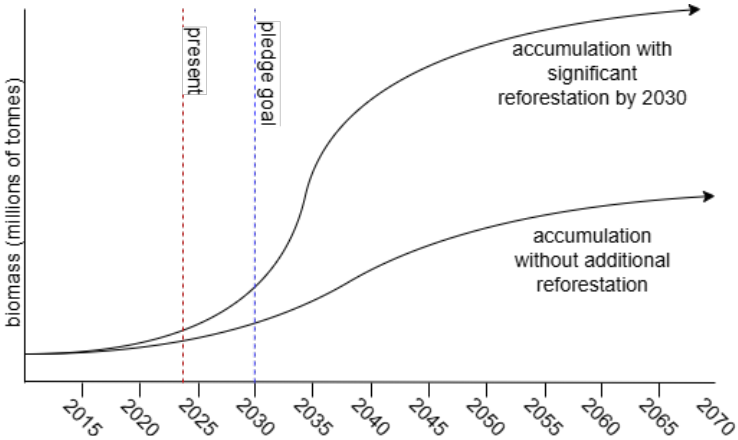

Figure 3: Biomass prediction. There will be a significant change in biomass accumulation depending on the amount of reforestation. This study aims to determine the magnitude.

[1] 58.4 tonnes/hectare for similar species in China * 60,000 ha = 3,600,000 tonnes (Thevs et al., 2012)

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